EFFECT OF PROCESSING AND SUBSEQUENT STORAGE ON NUTRITION

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OBJECTIVE

- To determine the effects of thermal processing, freeze drying, irradiation, and storage time on the nutritional content of food
- To evaluate the nutritional content of the food items currently used on the International Space Station and Shuttle
- To establish the need to institute countermeasures

* (This study does not seek to address the effect of processing on nutrients in detail, but rather aims to place in context the overall nutritional status at the time of consumption)

BACKGROUND

- Food products for space food systems are processed to commercial sterility
- While heat sterilization is the most effective food preservation process, it affects vitamin and protein quality
- The dehydration process has the smallest impact on nutrients
- Micronutrient stability is dependent upon the composite macronutrients matrix
  - A kinetic model only provides an estimate of the remaining nutritional contents
  - It is difficult to extrapolate between systems
- Food Composition Database does not take into account the effects of processing

JUSTIFICATION

- Food with a 3-5 year shelf-life will be required for a mission to Mars
  - Nutrient loss during processing and subsequent storage can be significant
- Nutrition requirements are delivered via the food system
  - The quantity of nutrients, e.g. vitamins, at consumption is currently unknown
- Nutrients play a vital role in facilitating the capability of astronauts to tolerate physiological changes
  - As mission durations increase, physiology changes gain importance

DELIVERABLES

- Conduct a literature review to better understand the potential effects of retorting, freeze drying and irradiation on nutrient loss
- Determine the effect of processing on representative flight food products by comparing the calculated nutrition to the actual nutrition one month after processing
- Determine the effect of subsequent storage on nutrition by comparing the one month nutrition analysis results with those at 1 year and 3 years
- Determine the capability of the current food system to provide adequate nutrition for long duration missions

Exploring COUNTERMEASURES

- Optimization of process, packaging, and storage conditions for nutrient retention
- Exploration of alternative sterilization methods
- Maximization of available nutrients by reformulation using ingredients with dense intrinsic nutrients
- Treatments with food additives to provide nutrients, e.g. antioxidants
- Fortification with stable nutrient forms, e.g. encapsulation, chelating, analogs, etc.
- Cultivation of quick growing fruits, vegetables, yeasts to deliver essential nutrients

RESEARCH PROTOCOL

- Ten to twelve processed food items will be selected per year for five years
- Nutritional profile will be determined:
  - 1 month after processing
  - 1 year after processing
  - 3 years after processing
- Comparing
  - calculated vs. analyzed
  - 1 month vs. 1 yr vs. 3yrs
- Until a need for countermeasures is established

Effect of Processing on Nutrition

Nutrients which are sensitive to heat, light, oxygen or pH are easily destroyed during processing, e.g. vitamins C, B1

Losses are related to the total energy input, physicochemical state of water

Minerals are not significantly affected by processing, but bioavailability may change

Relativity of nutrient retention:
Freeze-dried > Thermostabilized

Max Lost %	Nutrient	Heat	Light	Oxygen	pH <7	pH =7	pH >7
100	Vitamin C	U	U	U	S	U	U
100	Folic acid	U	U	U	U	U	S
80	Vitamin B1	U	S	U	S	U	U
75	Vitamin B2	U	U	S	S	S	U
75	Vitamin B3	S	S	S	S	S	S
60	Biotin	U	S	S	S	S	S
55	Vitamin E	U	U	U	S	S	S
50	Pantothenic acid	U	S	S	U	S	U
40	Vitamin A	U	U	U	U	S	S
40	Vitamin D	U	U	U	S	S	U

U: unstable S: stable

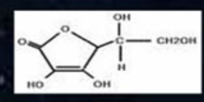
Effect of Subsequent Storage on Nutrition

- Nutrient changes in bioavailability due to:
  - oxidation
  - photochemical reaction
  - complex formation
  - decomposition
- Deterioration determined by:
  - initial composition, e.g. crystalline & amorphous structure
  - distribution & thermodynamic state of the water
  - environmental factors, e.g. moisture, gases, temperature
  - barrier provided by packaging

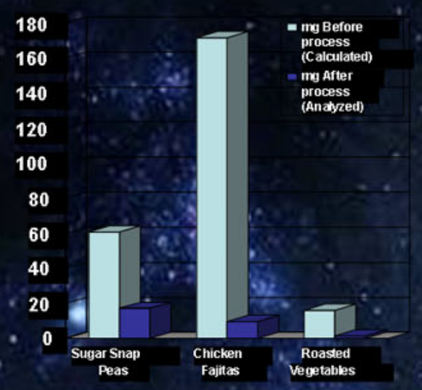
Nutrient	High Aw	Temp.	O_2	pH <7	pH =7	pH >7
Vitamin C	U	U	U	S	U	U
Folic acid	U	U	U	U	U	S
Vitamin B1	U	U	S	S	U	U
Vitamin B2	U	U	U	S	S	U
Vitamin B3	U	S	S	S	S	S
Biotin	U	U	S	S	S	S
Vitamin E	U	U	U	S	S	S
Pantothenic acid	U	U	S	U	S	U
Vitamin A	U	U	U	U	S	S
Vitamin D	U	U	U	S	S	U

U: unstable S: stable

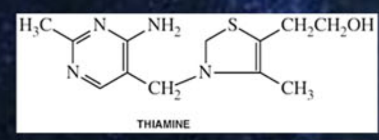
Vitamin C



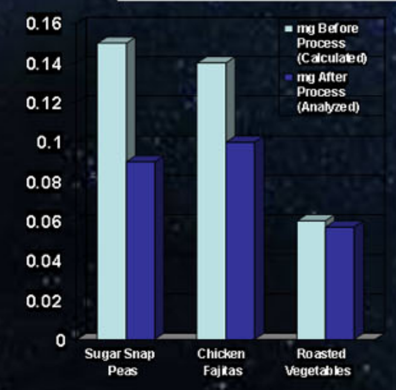
- Vitamin C or Ascorbic acid:
  - white, highly water-soluble
- Humans cannot manufacture vitamin C
  - absence of L-gulonolactone oxidase
- Natural dietary sources:
  - fresh fruits
  - fresh vegetables
  - fresh meats
- During processing:
  - significant loss from chemical degradation
  - degradation under aerobic & anaerobic conditions
  - leaching into cooking water
  - decomposed at 190°C



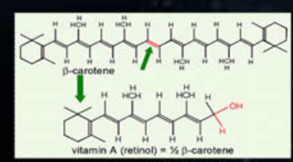
Vitamin B1



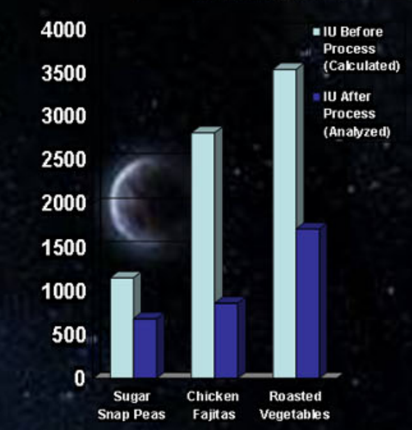
- Vitamin B1 or Thiamine:
  - colorless, water -soluble
- Cannot be stored in the body
- Natural dietary sources:
  - yeast, wheat germ
  - meats
  - fresh vegetables
  - whole-grain foods
- During processing:
  - leached into cooking water
  - degraded by alkaline pH and sulfite
  - destroyed by thiaminase
- During storage:
  - lost even under favorable storage conditions



Vitamin A



- Vitamin A or retinol:
  - pale prisms, fat soluble
- Natural dietary sources:
  - retinol from animals: fish oils, liver, organ meats, milk
  - carotenoid from vegetables, e.g. carrot, spinach
- During processing:
  - thermal transformation
  - fragmentation in high temperature
- During storage:
  - susceptible to oxidation, both chemical & light-catalyzed
  - UV degradation



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